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Siting Renewable Energy Facilities

*A Spatial Analysis of
Promises and Pitfalls*

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Abstract

Recent efforts to site renewable energy projects have provoked as much, if not more, opposition than conventional energy projects. Because renewable energy resources are often located in sensitive and isolated environments, such as pristine mountain ranges or coastal waters, siting these facilities is especially difficult. Moreover, the viability of different renewable energy projects depends not only on complex economic and environmental factors, but also on the availability of supporting infrastructures, such as transmission lines. This paper examines the spatial relationships between four types of renewable energy resources – wind, solar, geothermal, and biomass – and an empirical measure of state-level transmission-line siting difficulty. Analyses explore the locations of renewable resource potential relative to areas of high siting difficulty, state electricity demand and imports, and states with renewable portfolio standards (RPSs). Major results reveal that state resource potential varies, and siting is significantly more difficult in states that import electricity and those with RPSs. These results suggest that states with the greatest incentives to develop renewable energy also face the most serious obstacles to siting new facilities.

Key Words: siting, renewable energy, transmission lines, wind, solar, geothermal, biomass, geographic information systems (GIS), renewable portfolio standards (RPS)

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Introduction

Support for new renewable energy development in the United States has grown increasingly broad and diverse in recent years. With the rise in oil and natural gas prices and related global political uncertainties, renewable resources have emerged as attractive alternatives to conventional fuels. Although renewable energy was once regarded as a niche market embraced primarily by environmentalists, supporters' agendas now vary widely. Several broader reasons for promoting renewable energy projects have taken hold.

First and foremost, renewable energy is increasingly viewed as a new avenue for local and regional economic development. States have embraced the promise of local job creation. Second, with national concerns about energy security and electric reliability, renewable resources present new and comparatively clean and secure options for diversifying supply. Third, national attention to energy imports has been paralleled by state-level interest in reliably meeting growing electricity demand with increasingly constrained generation capacity and aging transmission infrastructure. Fourth, renewable energy also provides an alternative to conventional facilities for mitigating local environmental concerns, such as conventional air pollution. Finally, renewable energy expansion has been advanced as a serious and necessary measure to reduce greenhouse gas (GHG) emissions and mitigate global climate change.

To respond to the anticipated benefits of new renewable energy development in the United States, states and regions have implemented a range of supporting programs and initiatives, the most widely recognized of which are renewable portfolio standards (RPS). While some states and regions support renewable energy for multiple reasons, their priorities and motivations for supporting specific types of plans vary widely. For example, Massachusetts explicitly describes its RPS as a step toward mitigating GHGs and addressing the growing problem of climate change, while Texas has an RPS that focuses primarily on economic development and improved electric reliability (Rabe 2006). These differences underscore both the dynamic promise and potential pitfalls of large-scale renewable energy development today.

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In spite of the national attention to renewables, siting renewable energy facilities is still particularly difficult, and the problem is poorly understood. This paper develops a spatial model to compare the locations of renewable resource potential for four major resources – wind, solar, biomass, and geothermal – with a related measure of transmission-line siting difficulty. The goal of this paper is to evaluate the inherent spatial constraints on renewable resources and their implications for serving growing energy demand, especially in states that currently import electricity and those that have renewable portfolio standards in place. The main questions addressed here are as follows:

- What are the opportunities and barriers to displacing current state electricity imports with local renewable resources?
- How is renewable resource potential spatially distributed across states with RPSs compared to those without standards?
- Where are renewable resources relative to areas of high siting difficulty?
- Does siting difficulty vary across states with RPSs and those that import electricity compared to other states?
- What are the implications of the spatial distribution of renewable resource potential and siting difficulty for new development?

The next section of this paper provides a general overview of siting constraints facing both conventional and renewable energy facilities. Subsequent sections of this paper present a measure of transmission-line siting difficulty as a marker of related renewable energy siting challenges and develop spatial analyses using geographic information systems (GIS) to evaluate renewable resource potential in states with net imports, RPSs, and high siting difficulty. The final sections summarize the major findings of these comparative spatial analyses and discuss their potential impacts and policy implications for the future of renewable energy development.

A General Picture of Siting Difficulty

Although enthusiasm for renewable energy has grown, siting major energy facilities has become increasingly difficult, a trend that has not gone unnoticed. Energy and electricity industry professionals and policy groups have developed a variety of studies and strategies for mitigating siting difficulty for a range of new facilities from new power plants to liquefied natural gas terminals to transmission lines (NCEP 2006). However, siting remains a broad and complex problem, affecting both conventional and alternative energy facilities, for which solutions are not obvious or well-understood.

The most commonly identified causes of siting difficulty fall into three main categories: public opposition, regulatory roadblocks, and environmental constraints (Vajjhala and Fischbeck in press). Together these categories encompass any combination of obstacles to the process of finding locations for new facilities, including public opposition; environmental, topographic, and geographic constraints; interagency coordination problems; and local, state, and federal regulatory barriers to permitting, investment, and/or construction. In addition to these constraints, financing of new facilities remains insecure and growing siting issues have only compounded investment uncertainty. Given the complexity of the current investment landscape, it is important to note that this paper focuses specifically on siting issues independent from other external barriers to investment.

While the problems of siting most new facilities are now widely recognized, strategies for mitigating siting difficulty are less agreed upon. Policymakers have focused on state, regional, and national proposals, most recently with the creation of integrated federal energy corridors mandated by the Energy Policy Act of 2005. States and municipalities, on the other hand, have implemented myriad stakeholder participation programs and a variety of smaller-scale agency initiatives and siting process changes.

Public Opposition

Public opposition to siting is now so commonplace that it is frequently disparaged as the primary barrier to any new development. The term NIMBY, or not-in-my-backyard, has become part of the national vocabulary to the point where it has been replaced by the new term BANANA, build-absolutely-nothing-anywhere-near-anything. The transition from NIMBY to BANANA marks a turning point in public influence on facilities siting projects.

Major energy facilities were once sited based primarily on technical considerations using a “decide-announce-defend” approach; however, as more and more projects were delayed or cancelled because of public opposition, stakeholder participation and early citizen involvement have become cornerstones of major siting efforts. Even though intuition suggests that communities concerned with environmental issues would be more likely to accept renewable energy facilities than more polluting facilities, renewable plants still face significant opposition for their potential negative aesthetic and environmental impacts. The most recent and notorious example of this trend is the Cape Wind project, a 420MW offshore wind farm proposed for Nantucket Sound. This project epitomizes the complex political and social constraints on siting generally and new renewable energy development specifically.

Regulatory Roadblocks

Although public opposition to new energy projects is perhaps the most well-known constraint on siting processes, regulatory hurdles remain a costly, time-consuming, and unpredictable part of the problem. In many states, regulation is fragmented across multiple agencies, permitting and licensing processes are not standardized, and there is little in the way of established or timely review at the national, state, or local levels. Projects like transmission lines that can span multiple jurisdictions face even greater inter-agency coordination hurdles and redundant requirements than other types of facilities.

In the case of renewable energy facilities, these issues are compounded by a lack of regulatory familiarity with renewable projects and technologies. Furthermore, as Kahn (2006) describes, “Fossil-fuel power plant sponsors enjoy an important siting advantage over renewables: they can, within certain parameters, select the government agency that will approve or deny their projects. Renewable energy cannot.” By selecting project sizes and locations strategically, conventional power plant developers can avoid specific agencies or review requirements. In contrast renewable energy developers have far fewer alternatives.

Environmental Constraints

The most fundamental but perhaps least discussed siting constraint is the physical or environmental characteristics of the site itself. Technical and engineering considerations drive the earliest stages of project decisionmaking and identification of site alternatives. Put simply, in order to be economically viable, wind farms must be sited where the wind is blowing. Physical conditions on a potential site, including variations in topography, local ecology, and land cover, influence the structural and mechanical limits of different project designs, thereby affecting the cost and viability of a proposal. In the case of renewable energy facilities, these conditions include the availability and predictability of the resource itself.

Other limits on site selection include the links between related facilities. For example, transmission lines typically have inflexible endpoints, such as a pre-determined generating plant or a substation, so avoiding difficult areas completely is rarely an option. Instead, planners are forced to make trade-offs between project attributes and site characteristics, and rarely does one alternative dominate all others.

Renewable energy projects face some of the most significant environmental obstacles. Not only are renewable resources typically confined to pristine, isolated parts of the country but these resources are often inflexible. Kahn (2000) neatly captures this dilemma in the statement, “in developing a renewable power plant, it is the site that chooses the project, not the reverse.”

System Barriers

In addition to the general environmental limits discussed above, renewable projects are even further constrained to a limited portfolio of site alternatives by their access to supporting facilities like transmission lines. While all major energy facilities require some connection to existing pipeline, transmission, or other distribution infrastructure, renewable energy is particularly dependent on access to these existing systems. Because renewable resources are highly site specific, siting processes often require trade-offs between the highest quality resource locations and proximity to other infrastructure, like power lines (McVeigh et al. 1999).

Not only is availability of transmission a major issue, but there are other physical limitations of the grid specific to renewable energy. To varying degrees, renewable resources are intermittent, only available at certain times of the day or year. The changing availability of these resources and their unpredictability impose serious technical constraints on a grid that requires extremely tight coordination and control of electricity dispatch and delivery.¹

The Challenge of Siting Renewable Energy

Siting in general is hard, and renewable energy facilities face even greater challenges. Three of the most important obstacles are as follows: renewable fuels are inflexible, renewable energy facilities and transmission lines are tightly coupled systems, and renewable resource sites have limited overlap. The first of these constraints is the most intuitive. Renewable resources are immobile: natural gas or coal can be readily stored and shipped to a wide range of locations, but the wind is blowing where and when it is blowing.

Given this first constraint, the second is also apparent. As site-specific resources, renewables are highly dependent on the availability of infrastructure, like transmission lines, to reach remote sites and ship power out. The third obstacle is perhaps the most important, but the least obvious. While all energy facilities are site specific to varying degrees, potential sites for renewable energy facilities allow fewer options for the types of facilities they support. For example, an industrial site near a population served, with access to the required fuel supply, and other generally desirable qualities could theoretically support either a coal plant or a natural-gas fired plant within a given radius. However, a good site for a new wind farm is not likely to support solar power or any other type of renewable energy facility in any proximate location,

¹ Cassaza (1993) present an excellent general overview of the operation of the transmission system, basic structural stability and thermal limits of the grid, and potential problems posed by intermittent renewable resources.

especially with the specialized planning required. If an original proposal fails, it is highly unlikely that demand can be met with other renewable resources. As a result, alternatives are far fewer and farther between for renewable energy developers.

Given all of these specific obstacles and challenges, what is the future of large-scale, grid-connected renewable energy development? Several recent policy proposals and initiatives have emerged to address these issues. The most widespread of these policies are state RPSs. As discussed earlier, state priorities vary significantly and standards range from modest preliminary additions of renewables, such as the mandate to include 1.5-percent renewable energy by 2007 in Pennsylvania, to ambitious proposals for significant long-term change, such as the 33-percent target in California by 2020 and 25-percent in New York by 2013 (Rabe 2006).

Although RPSs and related initiatives are an important step forward to supporting renewable energy development, most of these policy proposals focus on structures to promote investment and not on interventions to mitigate siting difficulty. As a result, siting difficulty facing primary facilities, renewables, and support infrastructure, like transmission lines, could significantly affect states' ability to serve growing demand with renewable resources.

Transmission of Renewable Energy: A Case of Gridlock?

Siting both a renewable energy facility and the necessary transmission infrastructure to support a new project reflects a classic chicken-and-egg problem. Without adequate and accessible transmission capacity, renewable projects are unlikely to cross the threshold of economic viability, and without adequate generation capacity to justify new transmission construction, investment in new lines also is unlikely to occur. A recent example of this paradox is the growth of wind power in West Texas in the last decade. As Rabe (2006) describes:

“The unexpectedly rapid development of wind energy in remote sections of Western Texas placed significant demands on the relatively modest transmission systems that deliver electricity to areas of high demand. This constraint is linked with a larger challenge in Texas, and many other parts of the country, to upgrade and expand transmission capacity to ensure more efficient electricity distribution. ... Texas faces a particularly acute challenge and the new legislation calls upon the [Texas Public Utilities Commission] ‘to construct transmission capacity necessary’ to deliver anticipated expansion of renewables. Implementation of this provision may be the single most important factor in determining the effectiveness of the new RPS.”

Overall, the development of both intra-state and inter-state transmission capacity is a necessary prerequisite for any considerable renewable energy penetration into the market in coming years. As a result, the difficulty associated with siting transmission lines provides an important litmus test of the potential difficulty facing new renewable energy development.

A Measure of Transmission Line Siting Difficulty

In earlier work, Vajjhala and Fischbeck (in press) developed a quantitative measure of transmission line siting difficulty. Analysis was based on the creation and statistical aggregation of four independent indicators of siting difficulty.² The resulting quantification of state siting difficulty provides a measure independent of the common causes and localized effects of siting problems. State siting difficulty scores ranged from -3 to +3, where zero equals average siting difficulty across the United States and states with below-average siting difficulty have negative scores while those with greater than average difficulty have positive scores.

Figure 1 shows the relative geographic distribution of siting difficulty and transmission demand (the need for new capacity) across the continental United States. States that appear in the darker colors on the map have above-average or higher siting difficulty, and states that are lighter colored have below-average siting difficulty.³ States like Connecticut and California, with above-average transmission demand and siting difficulty, appear in the darkest shade on the map; Mississippi, Nevada, and other states with below-average difficulty and demand appear in the lightest shade. As the map illustrates, siting difficulty is widespread and it varies significantly across states and regions.

² The four indicators included economic, geographic, construction, and perception based metrics. For more information on the process used to develop this measure and detailed results, see Vajjhala and Fischbeck's paper in press, "Quantifying Siting Difficulty: A Case Study of U.S. Transmission Line Siting."

³ Transmission demand (the need for additional capacity or lines) and siting difficulty are treated as related problems, where states with high need and incentive to build additional transmission capacity are understood to face a variety of constraints (of which siting difficulty is one) that have prevented them from adding lines. As a result, Figure 1 is divided into four quadrants with categories for both above- and below-average siting difficulty and transmission demand.

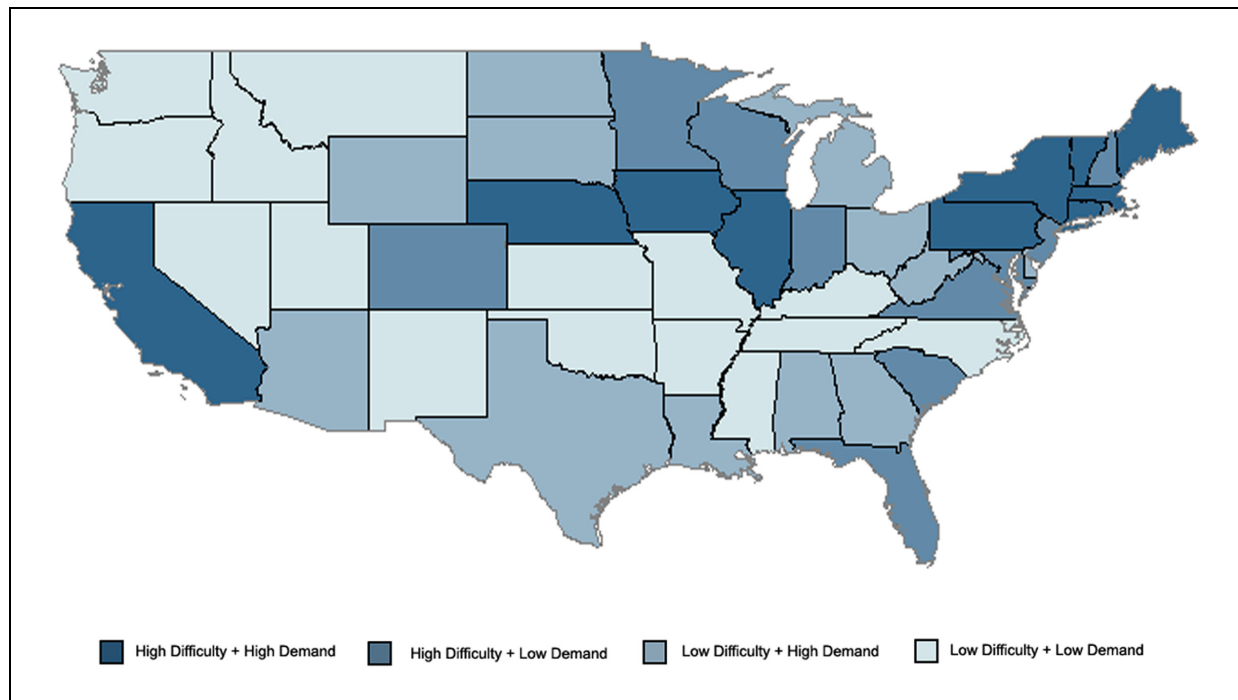


Figure 1. Map of transmission line siting difficulty and demand (Vajjhala and Fischbeck in press).

A Window onto Renewable Energy Siting Constraints

As discussed earlier, transmission line siting difficulty is an important indicator of potential siting problems facing new renewable energy facilities. As a critical support system for renewable energy facilities, not only are problems with siting new transmission infrastructure likely to reflect siting difficulty associated with new renewable energy development, but they are also likely to directly affect it. The often remote and pristine locations of renewable resources could make siting new transmission capacity in these areas even more difficult. As a result, the measure of siting difficulty and its spatial distribution provides a lower bound or conservative approximation of the siting difficulty associated with renewable resources.

Mapping Renewable Resources and Siting Difficulty

To evaluate the potential impact of siting difficulty on different renewable resources, this section develops a GIS analysis to compare the spatial distribution of four major renewable resources by state – wind, solar, geothermal, and biomass – with the measure of transmission line siting difficulty described above. Each of these resources is described briefly here, and the results

of the comparative spatial analyses are then used to evaluate the potential implications for changing state electricity demands and RPSs.

Spatial Distribution of Renewable Resource Potential

In total, renewable energy from non-hydroelectric sources makes up approximately 2 percent of total electric power generation (EIA 2005), but according to EIA estimates from the early 1990s if renewable resources were economically exploitable they would “account for more than 93 percent of total U.S. energy resources.” (EIA 1993).

The analyses here focus specifically on this concept of renewable energy resource potential. Although renewable resources are abundant, they are not all created equal and are available in different locations, with varying frequency and quality. For example, wind speed and consistency is a major determinant of the desirability of different potential wind sites. How often and how fast the wind is blowing drives potential electricity output and thereby the economics of a project. Because potential is solely a measure of resource availability, not necessarily its accessibility, which specific projects are economically viable depends on a complex combination of factors, including topography, land cover, and a host of other physical considerations.

This section centers on resource potential to evaluate the promises and pitfalls of major utility-scale growth of four renewable resources – wind, solar, geothermal, biomass. Analyses are based on maps and data from the National Renewable Energy Laboratory (2006) and the Department of Energy (2006). Using standard measures of total resource potential for each resource, an area-weighted average distribution of each resource was calculated by state.⁴

For the case of wind power, this average was calculated based on wind power classes. Power classes are detailed measures of wind speed and power density ranging from Class 1 with low wind speed of 10m/s at a height of 10m above ground and a power density of 100W/m² to a maximum of Class 7 with a high of 21m/s and 1000W/m². Using GIS, the total area within each power class for every state was calculated to find the average power class for an entire state. For

⁴ For all four resources, measures of total resource potential, not just viable potential, are evaluated. For example, the measure of wind potential includes all seven wind power classes, even though utility-scale applications typically require Class 3 wind or better. The reason for this is that given the variations in technological development and deployment for each of these types of energy it is not clear what is viable at a large scale or in the long-term. An analogous argument is the notion of “peak oil” which suggests eventual depletion of global oil resources. Just as estimates of total oil reserve capacity continue to increase with rising prices and improved technologies, thresholds for and estimates of useful renewable resource potential are also likely to change in coming years.

example, Mississippi, which is entirely in the wind power class 1, has an average wind power class of 1. In contrast, Colorado which spans multiple power classes has an average of 3.47.

While this average gives an overall picture of resource availability and quality, specific sites within states could easily be more or less promising than other sites, especially for utility-scale applications. Additionally, a state with all of its high power-class wind sites on mountain ridges could face much higher siting difficulty than a prairie state with comparable wind resources; a good comparison would be Vermont and Montana which both have similar average wind power classes of 3.85 and 3.98 respectively.

Solar power potential was calculated using a similar method based on average daily insolation values for flat-plate collectors, like photovoltaic panels.⁵ Values for this measure range from approximately 4 W/m² to 7 W/m². Geothermal energy, which is contained underground as reservoirs of steam, hot water, and hot dry rocks, relies on the extraction of heat as steam or hot water to power steam turbines and generators to produce electricity. The measure of potential for this resource is the average sub-surface temperature at a depth of 6km (DOE 2006).⁶

Finally, total state biomass potential was calculated based on estimates of the technical potential biomass resources currently available in the United States by county (dry tons per year), including crop residues, manure, forest and mill residues, and landfill and wastewater treatment gases (NREL 2006). Biomass, while already a major category of renewable energy, is the most different from the other three resources described above. Viable for both electricity production and vehicle fuels, this resource is perhaps the least constrained of the four. Biomass fuels can in theory be transported either as raw fuel or as liquid fuel, such as ethanol. However, with the limited infrastructure currently available for large-scale distribution, this resource still faces comparable siting constraints to wind, solar, and geothermal facilities.

The results of these initial spatial assessments reveal that renewable resource potential is widespread. Across the continental United States, 43 out of 48 states have above-average renewable resource potential for at least one resource and 28 states have above-average potential for two or more resources. In general, this is promising. This is not to say that select regions are not more favorable for certain types of renewable energy development, or that development of all resources in each state is economically viable, but this result highlights that there are few areas where renewable energy is not an option.

⁵ Insolation is a measure of the incoming solar radiation that reaches any object exposed to solar rays.

⁶ Because geothermal potential is based on estimated temperature ranges, scores from 1-4 were assigned for temperature categories from 0-100, 100-150, 150-200, and above 200 degrees respectively (DOE 2006).

These state profiles of resource potential, while broad, provide an important overview of the problem that is necessary for large-scale renewable energy development and penetration into the market. The next sections evaluate the specific distribution of resource potential in states with electricity imports, RPSs, and siting difficulty, respectively.

Displacing State Electricity Imports with Local Renewables

The recent surge of interest in renewable energy has been motivated to no small degree by anticipated local economic benefits (Bolinger et al. 2006). States that could reap the greatest economic benefits from “home-grown” renewable resources are those states that are currently importing high-priced electricity. This raises the question: do states that import electricity have greater or less renewable resource potential than states that are net exporters of electricity?

Figure 2 illustrates the results of statistical analyses comparing the average resource potential in states that are net importers and exporters of electricity. As the first three graphs show, the 18 importing states have slightly less wind and significantly less solar and geothermal resource potential than the 30 exporting states. Only in the category of biomass resources, do importers have a slight, but statistically insignificant, advantage over exporters.⁷

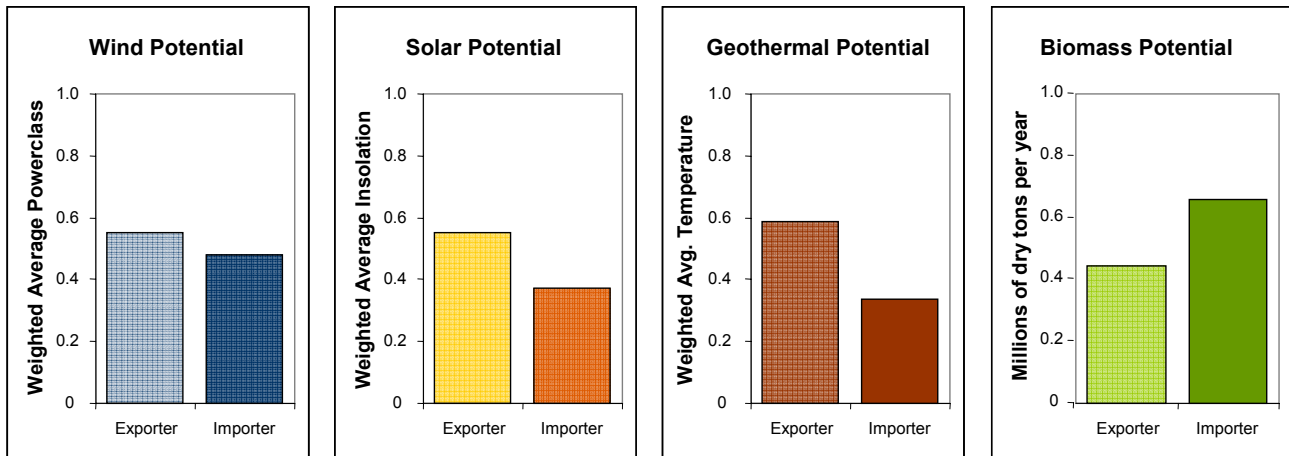


Figure 2. Differences in average resource potential across state net importers and exporters of electricity.

⁷ Average wind, solar and geothermal potential values for importing states are $\bar{x} = 2.29$, $\bar{x} = 4.74$ and $\bar{x} = 2.16$ respectively. Results of t-tests comparing importing with exporting states reveal that resource potential for wind, solar, and geothermal in these states is $\bar{x} = 2.55$, $t(37) = 0.98$, $p = NS$; $\bar{x} = 5.02$, $t(43) = 1.95$, $p = 0.029$; $\bar{x} = 2.48$, $t(43) = 2.14$, $p = 0.020$ respectively. Importers ($\bar{x} = 10.81$) have a slight but statistically insignificant advantage over exporters ($\bar{x} = 6.63$, $t(24) = -1.62$, $p = 0.059$) in biomass resource potential. All t-test results are based on analysis of raw data, but all values in the graphs in Figure 2 are normalized to allow for visual comparisons across resources.

Additionally, an evaluation of average state siting difficulty across net importers and exporters reveals that importing states face significantly higher state siting difficulty than exporting states.⁸ These results bring to light the fundamental variations across states, and underscore possible drawbacks associated with the current focus on primarily within-state resource development. Together these results raise questions of whether increasing demand and high-priced imports will provide sufficient motivation and economic incentives within states to overcome the joint problems of greater siting difficulty and lower renewable resource potential. One possible mitigating factor is the implementation of state RPSs.

Meeting State Renewable Portfolio Standards

Like the anticipated economic benefits of a shift to intrastate resources from high-priced imports, renewable portfolio standards also provide incentives for local renewable energy development. Most states, like Pennsylvania, have RPSs that explicitly focus on intrastate economic benefits and in some cases even more particularly on local job creation; therefore, access to intrastate resources is still a primary driver of renewable energy development.

Evaluating the distribution of resource potential across states with and without RPSs reveals no significant differences in resource potential. This lack of variation means that, unlike importing states, states with RPSs do not have less resource potential than those without standards for any single resource. However, these same states, like net importers, also face significantly higher siting difficulty than states without RPSs.⁹

In the few cases where the priorities represented by a state RPS are much broader in scope, this intrastate siting difficulty could have little impact on renewable energy investment. For example, in Massachusetts, the state RPS is a component of a larger climate change mitigation plan, and there is limited focus on intrastate economic benefits. Massachusetts, however, is a rare example of a state willing to rely on out-of-state resources to satisfy RPS requirements. Although many state RPSs allow for renewable energy credit trading and other outside resource use, significant siting constraints on intrastate resources, even in the absence of

⁸ Net importers of electricity have significantly higher average state siting difficulty ($\bar{x} = 0.55$) than net exporting states ($\bar{x} = -0.33$, $t(27) = -2.98$, $p = 0.003$).

⁹ States with RPSs have significantly higher average state siting difficulty ($\bar{x} = 0.58$) than states without current standards ($\bar{x} = -0.45$, $t(39) = -4.05$, $p = 0.0001$).

geographic limits on resource potential, could present a major obstacle for renewable energy development in practice.

Making the Most of Renewable Resource Potential

Although siting difficulty has the potential to negatively affect the outlook for renewables both in states with RPSs and those that import electricity, the direct spatial relationship between resource potential and states with high siting difficulty has positive implications for renewable energy development. States with below-average siting difficulty have significantly higher solar and geothermal resource potential.¹⁰ This result has positive implications for the future of both solar and geothermal development. As the most uncertain and currently least cost-effective of the major renewable resources, both solar and geothermal technologies could benefit from having areas of high resource potential in regions of low siting difficulty, allowing technologies to be more readily deployed and for new facilities to be tested. In this manner, siting difficulty, to greater or lesser degrees for different resources, could alter the path of new technology development and deployment.

Summary of Major Results

To summarize, the major results from all of the analyses in this paper are as follows:

1. *Renewable energy potential is widespread.*

Contrary to the popular belief that certain types of renewable energy exist only in specific geographic regions, renewable energy potential is widespread. Different states have different amounts and combinations of resources, but 43 out of 48 states have above-average potential for at least one or more renewable resources. This is promising. Few states are completely handicapped by a lack of potential resources.

2. *States that are net importers of electricity have significantly less overall resource potential than states that are net exporters of electricity.*

States with net electricity imports have incentives to take advantage of lower-price renewables to displace higher price imports, but these same states have less resource

¹⁰ Average solar and geothermal potential for low siting difficulty states are $\bar{x} = 5.10$ and $\bar{x} = 2.51$ respectively. Results of t-tests comparing low difficulty with high difficulty states reveal that resource potential for solar and geothermal in these states is $\bar{x} = 4.69$, $t(45) = 2.92$, $p = 0.003$ and $\bar{x} = 2.17$, $t(45) = 2.33$, $p = 0.012$ respectively.

potential with which to do so. This result is particularly important because of the primary focus on the local economic benefits of intrastate resource development.

3. *States that are net importers of electricity also face significantly higher state siting difficulty than states that are net exporters of electricity.*

The additional constraint of siting difficulty further shifts the balance between the costs and benefits of intrastate renewables relative to the costs of electricity imports.

4. *Resource potential in states with RPSs is not significantly different from states without RPSs, but states with standards have significantly higher transmission siting difficulty.*

Although RPSs are intended to encourage investment in and construction of renewable energy facilities, significant siting constraints on in-state resources, even in the absence of limited resource potential, could reduce economic incentives to meet standards.

5. *States with below-average siting difficulty have significantly higher solar and geothermal resources potential than states with above-average siting difficulty.*

The combination of high resource potential and low siting difficulty could help support development of emerging solar and geothermal technologies and their deployment.

Policy Implications

States with the motivation (RPSs) and incentives (high-priced electricity imports) to develop intrastate renewable energy have limited resource potential and face higher siting difficulty than other states. Given this fact, intrastate solutions alone seem likely to fall short of anticipated development potential. If renewable energy is to become a significant proportion of total national electricity generation, then policy implications of this result are two-fold. First, this result highlights the need for programs at a larger scale than state RPSs to fully take advantage of regional incentives for and benefits of new renewable energy investment. Second, it shows that complementary, parallel policies need to be developed to overcome interstate and regional siting constraints to explicitly support any new regional renewable energy initiatives.

Two examples of current policies that begin to address these separate issues are renewable energy credit- and certificate-trading schemes (RECs) and separately energy and transmission corridors mandated by the Energy Policy Act of 2005.¹¹ For the example of RECs,

¹¹ See Berry (2002) for an overview of market trading of renewable energy credits.

trading regimes, in one sense, replace actual transmission capacity within markets with virtual exchanges of renewable energy. Although these schemes have shown some initial success, the playing field for renewable development is still not level (Berry 2002). Renewable facilities, while competitive in niche markets, are still not in a position to displace major conventional generation facilities without added transmission capacity. Moreover, the majority of REC and related programs are still fundamentally constrained by the total capacity in the market, which in turn is hampered by widespread siting difficulty.

Energy corridors on federal lands in the western United States and more general national interest electric transmission corridors are notable exceptions to the rule of market-oriented policy solutions. Federal energy corridor proposals are intended to integrate siting of new facilities, including transmission lines and natural gas pipelines, within the same rights-of-way and simultaneously reduce redundancy in permitting and licensing requirements for the segments of these projects on federal lands. The goal is specifically to mitigate the difficulty associated with siting supporting infrastructures and expand opportunities for competition.

Together, REC and corridor policies could significantly change the viability of currently remote renewable resources; however, it remains to be seen whether they will result in significant and favorable change. Even with effective incentives and corridors in place, interstate and regional cooperation will be increasingly important to develop necessary transmission infrastructure to support the stable access of distant and intermittent resources to the grid, and to realize broader benefits of renewable energy within competitive electricity markets.

Conclusions and Discussion

From both the energy security and climate change mitigation perspectives, business-as-usual is no longer an option, and no silver bullet exists for either problem. The focus must remain on incremental and aggregate solutions, of which renewable energy is one. For renewable energy to make significant strides in meeting these challenges and displacing conventional energy facilities, siting difficulty and its relationship to renewable resource potential must be given much higher priority.

Siting problems are not going away, and deregulated markets show few signs of effectively addressing siting difficulty. Waiting until “push comes to shove” for rising costs of conventional fuels to spur widespread and rapid growth of new renewable energy facilities in the larger competitive market presents its own dilemma. Because some renewable energy technologies and projects are still uncertain, and many facilities currently take longer to permit and build, in a crisis there will be no motivation to turn quickly to renewable capacity, unless

large-scale commercial applications have already been sufficiently tried, tested, and proven. As a result, addressing siting constraints relative to renewable resource potential and solidifying opportunities for effective, early renewable energy development is an important initial step toward meeting long-term national energy security and environmental quality goals.

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